THE STRATIGRAPHY AND STRUCTURE OF THE UPPER PALAEOZOIC SEDIMENTS OF THE SOMERTON–ATTUNGA DISTRICT, N.S.W.

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(Three Text-figures.)

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Synopsis.

Revision of the stratigraphy of the Upper Palaeozoic marine succession in the Somerton-Attunga district, west of Tamworth, N.S.W., has been necessitated by the recognition of two angular unconformities and two regionally persistent marker beds. These are the Bective and Onus Creek unconformities, the Keepit Conglomerate and the Tulcumba Sandstone. Because of the presence of the unconformities in the sequence in the Somerton-Attunga district, use of the Parry Group and the Goonoo Goonoo Mudstone (Crook, 1961) and the Manilla Group (Voisey, 1958) as units has been discontinued. Two new lithological units, the Keepit Conglomerate and the Tangaratta Formation, have been described. An attempt has been made to deduce the sedimentation of the lithologies in the succession, and it is concluded that there is a transition from turbidite and slump deposits in the lower part of the sequence to traction current deposits at the top. New structural elements, the Appleby Syncline, the Appleby Fault and the Clay Gully Fault, are described. The Devonian-Carboniferous boundary, which occurs in the Tangaratta Formation, remains to be accurately positioned.

INTRODUCTION.

The area with which this paper is concerned lies to the south of Manilla and to the west of Tamworth in New South Wales, and adjoins those mapped by Carey (1937), Crook (1961), Chappell (1961), and Voisey and Williams (in press). The rocks are Upper Palaeozoic sediments which lie in the Western Belt of Folds and Thrusts (Voisey, 1959).

W. N. Benson was first to map the much larger region which includes the Somerton–Attunga district, and described it under the heading of the Great Serpentine Belt of N.S.W. (see Benson, 1913). Since then problems have arisen regarding the detailed division of the stratigraphical sequence as explained by Carey and Browne (1938), Crook (1961) and Chappell (1961). In 1912 Cotton and Walkom noted the apparent Devonian–Carboniferous boundary at Carroll Gap, and on their map marked an approximate position of this boundary from Carroll Gap towards Tamworth. This boundary has never been properly defined. More recently differences of opinion have arisen regarding the actual stratigraphical division. Considerable thicknesses of mudstone, besides other rock units, are contained in the Baldwin, Barraba and Burindi portions of Benson's sequence and in some successions difficulty has been experienced in separating them. Crook (1961), because of apparent similarities in the mudstones, even included all the Barraba and Burindi in the formation which he called the Goonoo Goonoo Mudstone which, with the Baldwin Formation, was included in a new unit, the Parry Group. Working in the Keepit Dam area, Voisey and Williams (in press) found a distinct break at the base of the Tulcumba Sandstone which they took to be the base of the Carboniferous sequence and which marked a change in the character of the sedimentation from turbidite to traction current type. Hence, they retained the Baldwin Formation and Barraba Mudstone in the Manilla Group (Voisey, 1958).

However, the difficulties of reconciling the sequence below the Tulcumba with that observed elsewhere (Voisey, 1958; Crook, 1961) led to the view that there was an unconformity below the Tulcumba Sandstone, and this view was expressed by T. B. H. Jenkins (pers. comm.) and Campbell and Engel (1963, p. 57). It was realized that

Benson 1912 - 1920		Carey & Browne 1938	Voisey 1952-1958		Crook 1961			Chappell 1961		Voisey & Williams 1963	This Paper	
Burindi Series		Upper Burindi Series Lower Kuttung Series	Upper Burindi Group		Lower Kuttung Group					Merlewood Formation	Merlewood Formation	
		Lower Burindi Series	Lower Burindi Group		Parry Group	Goonoo Goonoo Mudstone		Burindi Group		Namoi Formation	Namoi Formation	
							Boiling Down Sandstone			Tuloumba Sandstone	Tuloumba Sandstone	
Barraba Series	Barraba Mudstone		Manilla Group	Barraba Mudstone				Manilla Group	Mandowa Mudstone	Missing in this Section	Onus Creek Unconformity	
							Cowrie Sandstone				Tangaratta Formation	Cowrie Sandstone
							Turi Greywacke					
							Garoo Conglomerate					Garoo Conglomerate
							Scrub Mt. Conglomerate			Mandowa Mudstone	Mandowa Mudstone	
							---Kiah-Lst.---		--Kiah-Lst.--		-------Kiah-Lst.-------	
											Keepit Conglomerate	
											Bective Unconformity	
	Baldwin Formation			Baldwin Formation		Baldwin Formation			Baldwin Formation		Baldwin Formation	

Table 1. A summary of Nomenclature applied to the stratigraphic column by previous authors.

the Somerton–Attunga district was critical as it adjoined the other areas where the various workers had obtained conflicting results, so work was commenced here on the suggestion of Professor A. H. Voisey, early in 1962.

R. Leslie recently conducted geological work in the area from Gravesend to Murrurundi and was able to recognize certain stratigraphic units and marker horizons throughout. The writer is indebted to him for certain useful suggestions, particularly relating to the unconformities which have become apparent in the area which he too was mapping during this period.

As different rock units were used in the areas adjoining the one mapped and Mr. Leslie's interpretation was not available, it was difficult to determine which nomenclature should be followed in this publication. An attempt has been made to retain as many older names as possible, so only the new terms Tangaratta Formation and Keepit Conglomerate, which are necessary in the revised interpretation, have been introduced. The use of the Parry Group and Goonoo Goonoo Formation (Crook, 1961) and the Manilla Group (Voisey, 1958) has been discontinued because unconformities are present in these units in the Somerton–Attunga district. The Mandowa Mudstone (Chappell, 1961) has been kept as a useful name to cover the Barraba Mudstone, much reduced from the original sequence described by Benson. The nomenclature has been summarized in Table 1. A definite transition from turbidites to traction current deposits is present in this part of the sequence.

The naming of the unconformities is thought to be a useful procedure, as reference is now being frequently made to one or other of them by those at present working in north-eastern New South Wales.

The classification of sediments used herein is that of Pettijohn (1957), supplemented by the descriptive classification of interbeds of laminated sediments proposed by Lombard (1963).

An attempt has been made to deduce the conditions of sedimentation through the sequence, on the basis of sedimentary structures and associations of sediments.

New structural elements described herein are the Appleby Syncline, the Appleby Fault and the Clay Gully Fault.

STRATIGRAPHY.

The stratigraphic rock units employed here are:

- Namoi Formation.
- Tulcumba Sandstone.
- *Onus Creek Unconformity.*
- Tangaratta Formation.
  - Gowrie Sandstone Member.
  - Garoo Conglomerate Member.
- Mandowa Mudstone.
  - Kiah Limestone Member.
- Keepit Conglomerate.
- *Bective Unconformity.*
- Baldwin Formation.

Rock Units.

The Baldwin Formation: The Baldwin Formation (Voisey, 1958) consists of greywackes, conglomerates, breccias and argillites. It conformably overlies the Tamworth Group and is unconformably overlain by the Keepit Conglomerate. The sediments below the Hyde Greywacke and above the Tamworth Group, as described by Crook (1961), are equivalent to the Baldwin Formation here defined. The Baldwin Formation contains two main lithologies. These are: (i) Fine silts and argillites interbedded with fine laminae of feldspathic arenite—Laminites II (Lombard, 1963); (ii) Coarse-grained labile greywackes which are green when fresh, buff to brown when weathered. Minor developments of calcilutites may be associated with the greywackes. In the Somerton–Attunga district argillites constitute the bulk of the Baldwin Formation.

(i) Laminites II: The argillites are medium to dark grey in colour, and occur in laminae 0·5 mm. to 1 cm. thick. The laminae are usually graded, and the grading is distinct because the silt sized particles tend to be lighter in colour than the finer clays. The argillite laminae may also show fine current ripple laminations and current bedding on a minute scale. Convolute bedding of closed cast type is common in the argillites.

The fine non-graded feldspathic arenite laminae, interbedded with the argillites, have scoured and filled them on a small scale. The arenites are well sorted, lack graded bedding, and sometimes show small scale boudinage, full-aparts, and small load casts. The argillites may contain small chips of argillite and arenite of Baldwin lithology. They usually occur in structureless bands of argillite 2–5 cm. thick. The feldspathic arenite laminae vary in thickness from the finest visible partings (which still remain prominent because of their pale colour) to 2 cm. thick.

(ii) Greywackes: The greywackes of the Baldwin Formation are poorly sorted sediments largely composed of andesitic detritus. When fresh they form outcrops of very hard grey-green rock. Argillite fragments oriented parallel to the bedding planes are a common feature of the coarser greywackes. A thick breccia bed, with a coarse greywacke matrix containing contorted slabs of banded argillite, is present in the formation (Map ref. 107 E., 322 N.). In the same locality a coarse feldspatholithic arenite, containing polymictic conglomerate lenses and large scale current bed foresets, is present beneath the breccia bed. Typical banded argillites occur above and below these sediments. Individual greywacke beds vary in thickness from a few inches to 30 feet. The Baldwin sediments have been described petrographically in detail by Chappell (1961) and Crook (1960).

Leptophloeum australe is present in the upper parts of the Baldwin Formation, and at Map ref. 095 E., 251 N. poorly preserved goniatites have been found.

The Keepit Conglomerate: The Keepit Conglomerate unconformably overlies the Baldwin Formation, and underlies the Mandowa Mudstone. Because of its competency, the Keepit Conglomerate outcrops more prominently than most sediments in this district, particularly at "Klori" trig. station. The type section of the Keepit Conglomerate is exposed on the southern flank of Klori hill (Map ref. 084 E., 267-N.) where the unit attains a total thickness of 345 feet. Table 2 describes the type section in detail. Leslie (pers. comm.) has correlated this unit with the Keepit Conglomerate which occupies a similar stratigraphic position at Keepit (Voisey and Williams, in press).

The base of the Keepit Conglomerate is variable. Where there is angular unconformity between the conglomerate and the Baldwin Formation, a coarse polymictic conglomerate with a discontinuous framework forms the basal phase. However, north of the Somerton–Manilla road (Map ref. 067 E., 262 N.), where the conglomerate overlies the Baldwin Formation with apparent conformity, the basal lithology is a coarse-grained greywacke containing large disoriented slabs of Baldwin argillite.

The Mandowa Mudstone: The Mandowa Mudstone (Chappell, 1961) conformably overlies the Keepit Conglomerate. It is overlain by the basal conglomerate of the Tangaratta Formation where this formation is present, and where the Tangaratta Formation is not present the top of the Mandowa Mudstone is marked by the base of the Tulcumba Sandstone.

The Mandowa Mudstone is a sequence of laminites II with thin sparse laminites I. The mudstones in the unit are less indurated and contain less silty material and noticeably more plant debris than the Baldwin argillites. They are often without sedimentary structures, but are sometimes finely laminated with oriented fine macerated carbonaceous plant debris. Small scale current bedding foresets and current ripple laminations are common in the mudstone, while graded bedding is rare.

Interbedded with the mudstone laminae are feldspathic arenite laminae. Prominent in these are small scale current bedding foresets and, at the tops of beds, current ripple laminations. They contain abundant fine plant debris and lack graded bedding. The mudstone and feldspathic arenite laminites II (0·2 mm. to 2 cm. thick) show minute vertical displacements, boudinage, and load casts. Contacts between the argillite and arenite bands are sharply defined. Single beds of coarse sediment thicker than 6 cm. (laminites I) have not been observed in the Mandowa Mudstone. Towards the top of the unit the arenite bands become thinner and less frequent and the argillite bands may comprise 85% of the sediment. *Leptophloeum australe* is common in the Mandowa Mudstone.

The Kiah Limestone Member: The Kiah Limestone member (Crook, 1961) is a very fine grained lithographic limestone that is sometimes present in the Mandowa Mudstone, a short distance (20–100 feet) above the top of the Keepit Conglomerate. The top and base of the unit are marked by the sharp change in lithology from lithographic limestone to mudstone laminae of the Mandowa Mudstone. In the Somerton–Attunga district it often lacks the pseudomorphous calcite crystals that are characteristic of the limestone elsewhere. Weathered specimens exhibit beds ⅛″ to 1″ thick. The beds are finely laminated and show low angle current bedding foresets and current ripple marks. This is the limestone noted by Cotton and Walkom (1912) at a number of points on the Tamworth–Attunga road (see Fig. 1). Pelagic fossils have not been found in the Kiah Limestone in this district, although Pickett (1960) found *Cymaclimenia borahensis*, a high Devonian ammonite, in the Kiah Limestone near Manilla. Crook (1961) found petioles of *Kalymma* Unger 1856 in *Leptophloeum australe* preserved in the Kiah Limestone. Crook found that the *Kalymma* Unger 1856 was a new species, but it showed affinities to those species found at the Devonian–Carboniferous boundary in the New Albany Shale of central Kentucky (Read, 1937). Crook placed the Devonian–Carboniferous boundary at the level of the Kiah Limestone horizon, which

TABLE 2.

Type Section of the Keepit Conglomerate, 400 Yards East of Klori Trig. Station.

Lithology.	Thickness.
Laminites I of the Mandowa Mudstone, containing *Leptophloeum*.	Top
Polymictic orthoconglomerate, with a notably discontinuous framework. Contains 25% pebbles, 75% tuffaceous coarse greywacke matrix. Pebbles are of greywacke and andesite lithology, are subrounded to subangular, very rarely rounded. Angular mudstone chips are common. Average pebble size, ½″–¾″ in diameter.	230 ft.
Buff-coloured coarse feldspathic arenite.	15 ft.
Coarse polymictic conglomerate, pebbles and boulders comprise 40% of the rock. Pebbles and boulders are rounded to subrounded, largest boulder 9″ in diameter, average pebble size ½″ diameter, greywacke pebbles most common.	10 ft.
Very coarse greywacke with flat mudstone chips and isolated pebbles.	16 ft.
Polymictic conglomerate with greywacke and rare andesite pebbles occurring in two size-ranges, ¼″–½″ and 4″–10″. Largest boulder 12″ in diameter. Pebbles and boulders comprise 60% of rock.	3 ft.
Fine conglomerate with rounded chert pebbles and continuous framework, largest boulder 4″ in diameter, average pebble diameter ½″–1½″.	4 ft.
Fine gravelly conglomerate with rounded pebbles, some siliceous mudstone chips and gravel matrix.	15 ft.
Coarse boulder bed with granite, acid volcanic and coarse and fine greywacke boulders 2′–5′ in diameter, with a discontinuous framework. Matrix of many smaller pebbles and greywacke bands.	30 ft.
Fine conglomerate with rounded pebbles of chert and greywacke composition.	6 ft.
Coarse conglomerate with rounded greywacke boulders up to 2′ in diameter.	3 ft.
Fine pebbly and gritty conglomerate with some small rounded boulders and some mudstone chips.	20 ft.
Total thickness	352 ft.
Laminites of Baldwin Formation.	Bottom

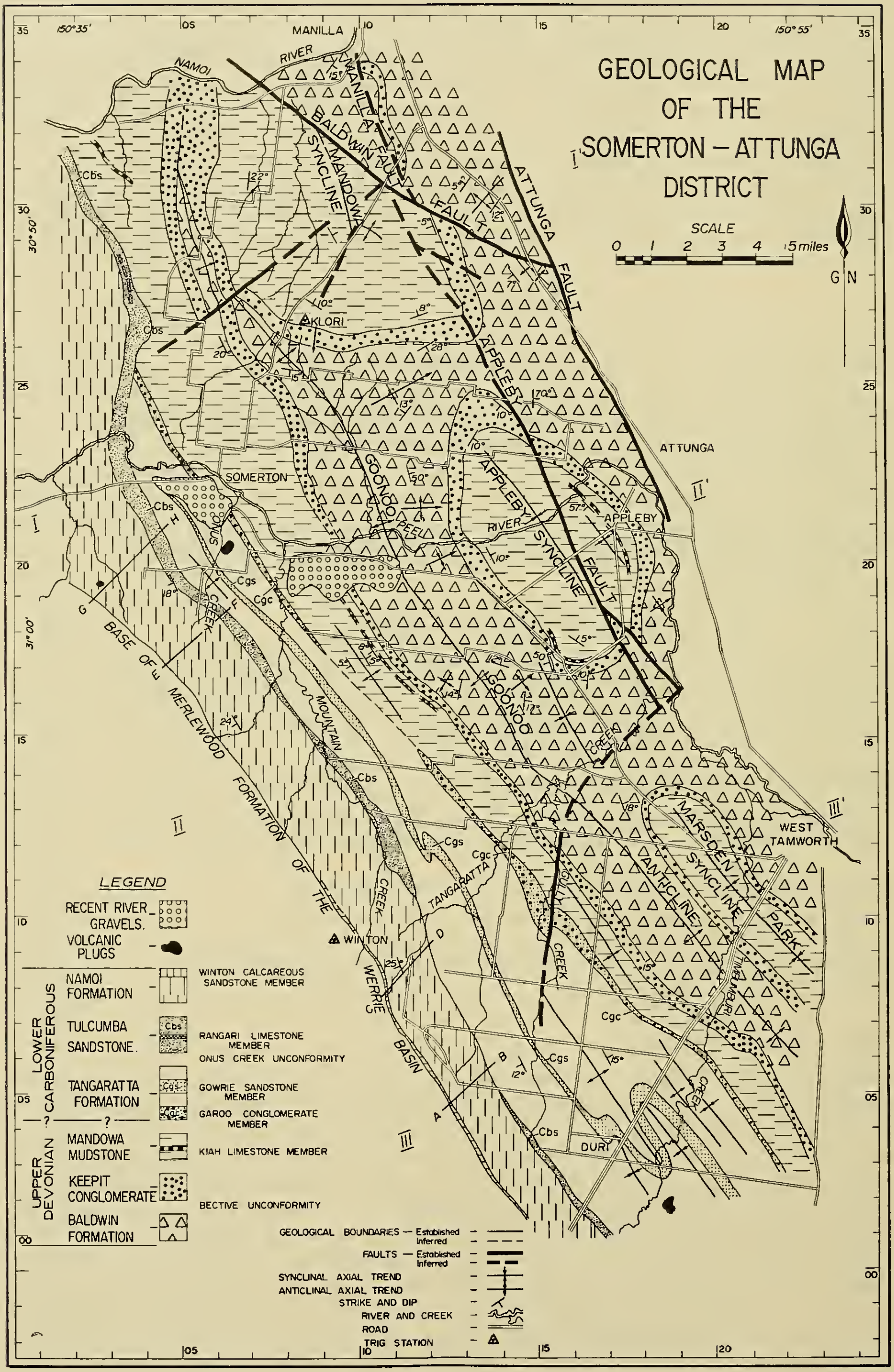
GEOLOGICAL MAP OF THE SOMERTON – ATTUNGA DISTRICT
SCALE
0 1 2 3 4 5 miles
G N
150°35'
150°55'
30°50'
31°00'
35
30
25
20
15
10
05
00
05
10
15
20
MANILLA
NAMOI RIVER
MANILLA FAULT
BALDWIN FAULT
MANDOWA SYNCLINE
ATTUNGA FAULT
APPLEBY FAULT
APPLEBY SYNCLINE
GOONOO GOONOO
PEEL RIVER
KLORI
ATTUNGA
SOMERTON
APPLEBY
ONUS CREEK
MOUNTAIN CREEK
BASE OF THE MERLEWOOD FORMATION OF THE WERRIE BASIN
TANGARATTA CREEK
MARSDEN SYNCLINE
ANTICLINE
PARK
TIMBUMBURI CREEK
WEST TAMWORTH
WINTON
DURI
Cbs
Cgs
Cgc
I
I'
II
II'
III
III'
A
B
D
E
F
G
H
LEGEND
RECENT RIVER GRAVELS.
VOLCANIC PLUGS
LOWER CARBONIFEROUS
NAMOI FORMATION
WINTON CALCAREOUS SANDSTONE MEMBER
TULCUMBA SANDSTONE.
RANGARI LIMESTONE MEMBER
ONUS CREEK UNCONFORMITY
TANGARATTA FORMATION
GOWRIE SANDSTONE MEMBER
GAROO CONGLOMERATE MEMBER
UPPER DEVONIAN
MANDOWA MUDSTONE
KIAH LIMESTONE MEMBER
KEEPIT CONGLOMERATE
BECTIVE UNCONFORMITY
BALDWIN FORMATION
GEOLOGICAL BOUNDARIES — Established Inferred
FAULTS — Established Inferred
SYNCLINAL AXIAL TREND
ANTICLINAL AXIAL TREND
STRIKE AND DIP
RIVER AND CREEK
ROAD
TRIG STATION

Figure 1.

he stated marked the upper limit of *Leptophloeum australe*, but the author has since found *Leptophloeum australe* in the Mandowa Mudstone just below the base of the Tangaratta Formation in a road section (Map ref. 155 E., 103 N.). The author feels that until palaeontological work is done on the Tangaratta Formation there is insufficient evidence to place the Devonian–Carboniferous boundary accurately in this part of the sequence.

The Tangaratta Formation: The Tangaratta Formation overlies the Mandowa Mudstone and is unconformably overlain by the Tulcumba Sandstone. The formation has not previously been recognized as a separate entity. The name derives from Tangaratta Creek where the unit is best exposed in the Somerton–Attunga district. The thickness of the Tangaratta Formation varies from 0 to 2,000 feet, and it thickens towards the south-east. The base of the unit in the Somerton–Attunga district is the base of the Garoo Conglomerate member, and the top of the unit is marked by the base of the Tulcumba Sandstone. The Tangaratta Formation is correlated with the central and part of the upper Goonoo Goonoo Mudstone described by Crook (1961). The Garoo Conglomerate and Gowrie Sandstone members (Crook, 1961) have been traced from the district mapped by Crook through the western part of the Somerton–Attunga district.

The Tangaratta formation is composed largely of interbeds of mudstone and arenite (laminites I and II). The laminites I and II are most distinct in the lower part of the Tangaratta Formation, where the three lithologies present are medium-grained and fine-grained feldspatholithic arenites and fine grey mudstone. Beds of medium-grained feldspathic arenite 2″–15″ thick (laminites I) are separated by similar thicknesses of laminites II—thin interbeds of fine feldspatholithic arenite and grey mudstone. Laminations present in each lithology are fine bedding laminations, current bedding foresets and current ripple laminations. Scour and fill is usually preserved at the top of the laminites II by the medium-coarse grained arenite beds, and truncated ripple marks are often present in these. Some groove casts and load casts have been observed at the top of mudstone beds. The ripple marks and current bed foresets indicate currents flowing most commonly from the south, but also sometimes from the opposite direction. Minute macerated plant remains are present in each lithology in great abundance, and long axes of the plant shreds show a preferred orientation about 350°–10°. Plant remains define fine bedding laminations in each lithology. The laminites I contain thin beds ¼″–½″ thick that are graded, although grading is not a feature of the whole bed. Grading is usually rare in the formation.

The laminites I and II become less distinct towards the top of the Tangaratta Formation where the characteristic lithology changes to buff-coloured mudstone. Beds of mudstone 3–10 feet thick are interbedded with ½″ thick bands of separate feldspar crystals interspersed in a mudstone matrix, and beds of tuffaceous feldspathic arenite 2″–18″ thick. The tuffaceous arenites are distinctly graded and they have scoured and filled the underlying mudstone beds. Scour and fill is also present within the mudstone beds which are laminated, the laminations being defined by fine carbonaceous plant debris. Graded bedding has also been observed in these mudstones. There is not, however, the distinct fine bedding that is common in the mudstones lower in the sequence.

The Garoo Conglomerate Member: The Garoo Conglomerate member (Crook, 1961) occurs at the base of the Tangaratta Formation in the Somerton–Attunga district. The unit conformably overlies the Mandowa Mudstone and is overlain by laminites I and II of the Tangaratta Formation. The base and top of the member are marked by the change in lithology from conglomerate and greywacke to mudstone and arenite laminites. In the Somerton–Attunga district the unit outcrops poorly. The typical lithologies of the member are basal coarse polymictic conglomerates overlain by fine greywacke and conglomerate lenses. The pebbles in the conglomerate are dominantly of andesitic, intermediate volcanic and greywacke lithology. Crook states that the Garoo Conglomerate reaches a thickness of 250 feet in the type section.

The Gowrie Sandstone Member: The Gowrie Sandstone member (Crook, 1961) is a coarse-grained arenite and conglomerate unit present in the upper part of the Tangaratta Formation. It is underlain and overlain by laminites I and II of the formation. Coarse-grained feldspatholithic arenite, and polymictic conglomerate lenses, in which the pebbles are usually no more than 6″ in diameter, are the typical lithologies of the unit. Large scale current bedding foresets have been observed in the thin arenite beds near the top of the member. Interbeds of laminites I and II mark the top of the member.

The Tulcumba Sandstone: The Tulcumba Sandstone (Voisey and Williams, in press) unconformably overlies the Tangaratta Formation, or the Mandowa Mudstone where the former unit is not present, and is overlain by the Namoi Formation. The top of the Tulcumba Sandstone is the top of the highest arenite bed in the unit. It has been found that the Boiling Down Sandstone (Crook, 1961) is the southern extension of the Tulcumba Sandstone. Leslie (pers. comm.) has demonstrated the regional persistence of the unit above the Onus Creek Unconformity.

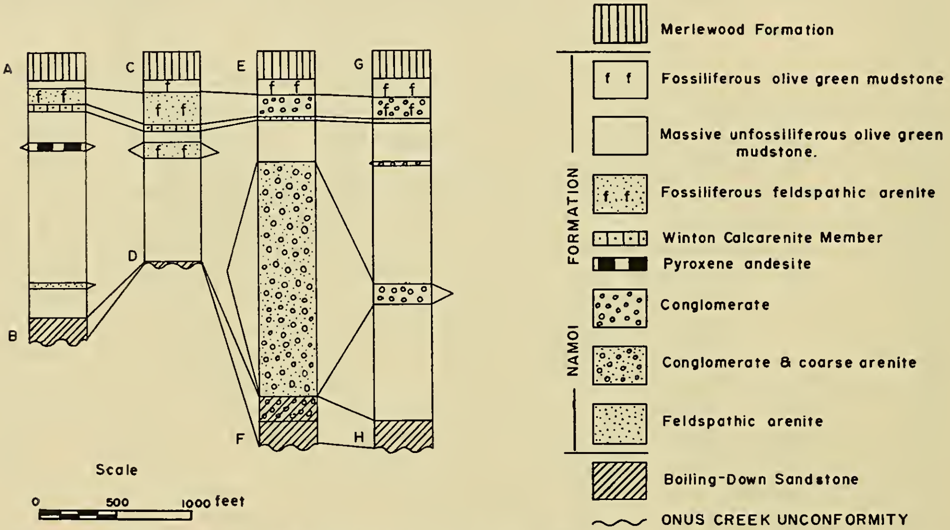
A
B
C
D
E
F
G
H
Scale
0
500
1000 feet
Merlewood Formation
NAMOI FORMATION
Fossiliferous olive green mudstone
Massive unfossiliferous olive green mudstone.
Fossiliferous feldspathic arenite
Winton Calcarenite Member
Pyroxene andesite
Conglomerate
Conglomerate & coarse arenite
Feldspathic arenite
Boiling-Down Sandstone
ONUS CREEK UNCONFORMITY

Fig. 2. Correlation of sections A-B, C-D, E-F, and G-H through the Namoi Formation and the Boiling-down Sandstone.

The Tulcumba Sandstone is a coarse to fine grained feldspatholithic arenite with some development of polymictic conglomerate, usually at the base of the unit, and some quartzo-feldspathic arenite. Marine and plant fossils are present in the unit. It is well bedded and large scale cross bedding foresets are common in the beds. A maximum thickness of approximately 150 feet has been observed in the Somerton–Attunga district. Large scale current bedding and calcareous feldspathic arenites at the top of the unit serve to distinguish it from underlying arenites.

The Rangari Limestone (Voisey and Williams, in press) is present in the Tulcumba Sandstone in the north-west part of the Somerton–Attunga district. This limestone member is one of the distinguishing features of the Tulcumba Sandstone. It is an oolitic limestone containing detrital fragments of brachiopods and crinoid stems.

The Namoi Formation: The Namoi Formation (Voisey and Williams, in press) is a sequence of mudstones containing minor calcarenites that lies conformably on the Tulcumba Sandstone and is overlain by the Merlewood Formation. The top of the Namoi Formation is marked by the base of the first conglomerate or arenite of the Merlewood Formation.

The Namoi Formation is the only unit in the district that outcrops well, and Figure 2 shows the representation of columnar sections measured in several places through the formation. The unit is correlated with the lower Burindi Series described by Carey and Browne (1938) and the uppermost part of the Goonoo Goonoo Mudstone (Crook, 1961).

The lower part of the unit is laminated mudstone containing discontinuous calcareous concretions and some interbeds of thin feldspathic arenite. Above this laminated mudstone is a thickness of fine-grained massive olive-green mudstone that breaks into small elongate fragments and is barren of fossils. There is a great abundance of brachiopods, crinoid stems and solitary horn corals in the mudstone in the upper part of the formation.

A notable feature of the middle Namoi Formation in the Somerton–Attunga district is the very local development of conglomerate and arenite lenses. The conglomerates are coarse and polymictic with boulders varying in diameter from coarse gravel size to 2 feet. Acid plutonics, intermediate and basic volcanics and greywacke boulders are present in the conglomerates which have a matrix of coarse sand. The arenites are coarse, cross bedded and fossiliferous.

The Winton Limestone Member: The Winton Limestone member, within the upper part of the fossiliferous mudstone of the Namoi Formation, is a persistent, cross bedded, sometimes fossiliferous calcarenite varying in thickness from 20 feet to 80 feet. The type section of this member is in Mountain Creek east of Winton Trig. (whence it derives its name) at map ref. 100 E., 093 N. The unit is oolitic in places, and crinoid stems are an abundant constituent of the rock.

Above the Winton Limestone member is a thickness of mudstone that is unfossiliferous and characteristically very pale green or yellow and contains in places "red bed" lenses. The top of the mudstone marks the top of the Namoi Formation.

UNCONFORMITIES.

Two angular unconformities have been noted in the sequence in the Somerton–Attunga district. Their regional persistence, as demonstrated by Leslie, has an important bearing on the interpretation of the tectonic history and stratigraphy of these sediments. It is proposed to name these unconformities the Bective Unconformity and the Onus Creek Unconformity.

The Bective Unconformity: The Bective Unconformity is the angular unconformity between the Baldwin Formation and the Keepit Conglomerate. The angle of unconformity between the two units is variable and may be as much as 90°.

Evidence for the unconformity: (1) The structural trends of the Baldwin and overlying sediments in places differ markedly. The Baldwin Formation is distinctly cross folded, while cross folding is only expressed by the formation of large scale domes and basins in the overlying sediments; (2) Strong angular unconformity between the two units has been observed at widely separated localities in the Somerton–Attunga district (e.g., at Map ref. 118 E., 263 N.; Map ref. 153 E., 169 N.; Map ref. 106 E., 250 N.); (3) Angular unconformities between the Baldwin Formation and the Keepit Conglomerate have been observed in exposures of the contact of the two units in the southern, central and northern parts of this belt of sediments by the writer and by R. Leslie (Leslie, pers. comm.).

The Baldwin Formation and the Keepit Conglomerate appear to be turbidite deposits. Crook (1959) suggested that paraconformities (Dunbar and Rogers, 1957) could be formed in turbidite sequences when turbidites were scoured by turbidity currents. There is no evidence, such as weathering, to suggest that the upper layers of the Baldwin Formation were subaerially eroded. Thus the erosion may have been accomplished by a mechanism such as postulated by Crook (1959), that is, scouring of the sediments by turbidity currents, or by deep sea traction currents, such as reported by Heezen (1959*a*, *b*).

An unconformity, in places as much as 90°, and a marked difference in structural trends between the two units, indicate that the Baldwin Formation was folded during or prior to the erosion of the upper part of the unit. A time break of some length is thus inferred.

The Onus Creek Unconformity: The Onus Creek unconformity is the angular unconformity at the base of the Tulcumba Sandstone.

Evidence for the unconformity: (1) The Tangaratta Formation is missing north-west of Somerton, where the Tulcumba Sandstone changes strike suddenly to form the eastern limb of the Belvue Basin (Voisey and Williams, in press) and directly overlies the Mandowa Mudstone. The Tangaratta Formation is a widespread unit elsewhere in this belt of sediments (Leslie, pers. comm.) and is therefore not merely a local sedimentary unit. The total absence of the unit indicates that at least 1,500 feet of sediment has been removed; (2) The strikes of the Gowrie Sandstone and the Garoo Conglomerate converge with the strike of the Tulcumba Sandstone (see fig. 1); (3) The Tangaratta Formation is folded into a series of gentle north-west trending folds, whereas the Tulcumba Sandstone and the Namoi Formation dip uniformly west, under the Werrie Basin—indicating that the Tangaratta Formation was folded prior to deposition of the Tulcumba Sandstone. The sudden change in facies also indicates that there was a time break following the folding; (4) Angular unconformity has been observed between the Tulcumba Sandstone and the Tangaratta Formation, for example, in Onus Creek (Map ref. 062 E., 193 N.) and at Keepit where an angular unconformity has been found between the basal Tulcumba Sandstone and the Mondowo Mudstone (Jenkins, pers. comm.). Here apparently all the Tangaratta Formation and part of the Mandowa Mudstone have been removed.

SEDIMENTATION.

In recent studies of some sediments and reviews of the literature dealing with marine sedimentation, Murphy and Schlanger (1962) and Dott (1963) have concluded that the single valid criterion distinguishing turbidites is the repeated occurrence of graded bedding. The presence of large scale current bedding foresets is the most widely accepted criterion for identifying a traction current deposit. Using these criteria, turbidites and traction current deposits have been identified in the Somerton–Attunga district. Subaqueous slide breccias, mudstones lacking in current structures, and tuffs are also present in the sequence. However, the mode of deposition of much of the sediment of the Mandowa Mudstone and the lower part of the Tangaratta Formation is not immediately apparent. These sediments contain abundant sedimentary structures which are listed in two groups, viz.: (i) those that have been found associated with well documented turbidites, and (ii) those that are normally believed to have been formed by the movement of sediment by traction.

(i) From Kuenen and Migliorini (1950), Kuenen (1953), Kuenen and Sanders (1956), and Dott (1963), the attributes of turbidites that are also features of the above-mentioned sediments include graded bedding; abruptly alternating coarse and fine beds; absence of wave ripple marks; channel scour; frequent "slump" structures; scarcity of benthonic life; load casting, convolute bedding; conglomerate interbedded with greywacke and lacking cross bedding; angular mudstone chips in greywacke or siltstone matrix; slumped boulder beds; worm trails preserved; flute and groove casts; shallow water organisms in a reworked condition when present.

(ii) Structures indicating the movement of sediment by traction are small scale current bed foresets; current ripple marks; oriented plant debris.

The structures listed under (i) may be found in sediments other than turbidites, as pointed out by Dott (1963), but when all or most of them occur in a sediment it is reasonable to conclude that it is a turbidite. In the Mandowa Mudstone and the lower part of the Tangaratta Formation, when these features are common in the sediment, repeated graded bedding does not occur, but there are occasional graded beds. This suggests that these sediments have been deposited by turbidity currents.

When the structures listed under (ii) are common, traction of sediment is evident. However, the structures may have been formed by the action of traction currents or by the winnowing of fine material at the tops of beds by turbidity currents. When they are common in sediments inter-bedded with sandstones that contain large scale current bed foresets, and the structures listed under (i) are minor, such sediments are probably traction current deposits.

The Baldwin Formation is a sequence of greywackes and repeatedly graded argillite units which alternate abruptly. Load casts, convolute bedding, conglomerate lacking current bedding foresets and interbedded with greywackes, angular mudstone chips in siltstone beds, scarcity of benthonic life and absence of wave ripple marks characterize the sediment of the Baldwin Formation and indicate that the greywackes and argillites are turbidites.

An exception is the thick feldspathic arenite which occurs towards the middle of the formation. This contains large scale current bedding foresets and orthoconglomerate lenses, and so indicates a distinct change in the sedimentation of the Baldwin Formation, for it suggests traction current deposition.

The rock overlying this arenite may be subaqueous slide deposit, as it consists of large angular disoriented blocks of argillite in a greywacke matrix. The overlying rocks represent a return to the normal condition of sedimentation of the formation.

The rare current ripple laminations in the argillites of the Baldwin Formation may be explained as the result of winnowing of fine material at the top of beds by turbidity currents.

The Keepit Conglomerate: This unit is mostly polymictic paraconglomerate and coarse gravel. These lithologies contain angular and sub-rounded as well as rounded boulders and pebbles, sparse reworked shallow water fossil remains, and large angular mudstone blocks. There is an excess of matrix over boulders in the conglomerate. These features are strongly suggestive of a turbidite deposit (Pettijohn, 1957). Minor lithologies which are sometimes present are a basal greywacke containing large slabs of argillite, and a very coarse boulder bed (present in the type section). These probably represent subaqueous slide deposits.

The Mandowa Mudstone and the Tangaratta Formation: These units are discussed together because they contain features indicating similar modes of sedimentation. Current ripple marks, fine laminations and abundant plant debris are common in the mudstones, and silty layers and graded beds are rare. These latter contain load casts, convolute bedding and groove casts. They thus contain sedimentary structures associated with turbidites and it is possible that they do in fact represent turbidites. The remaining mudstone beds are thin, laminated, and lacking in any current structures and seemingly have been deposited as a result of slow settling of mud.

The thin arenites of these units contain abundant current ripple laminations, small scale current bed foresets, groove casts, load casts and truncated ripple marks, and are well sorted, of wide lateral extent, and constant thickness. Thus the sedimentary structures are definitive neither of turbidity current nor of traction current deposition. Grading could be absent because of pre-sorting of the sediment and its absence is therefore not a criterion for traction current deposition. Because of the lack of any large scale current bedding and because of the presence of some thin fine-grained sediments which do show grading, it is possible that these arenites are also turbidites and that the current structures are due to reworking by turbidity currents. Gorsline and Emery (1959) found that similar laminites I were formed when turbidity currents moved sediments, already sorted by wave action in shallow water, down through submarine canyons into basins where they spread out and deposited thin beds of non-graded arenite.

The upper Tangaratta Formation consists of thick mudstone beds interbedded with thin tuffaceous feldspathic arenites of a different character from the arenites discussed above. The distinct grading in these arenites may have been produced by subaerial grading of tuffaceous material, as the tuffs show little reworking and do not contain current structures of any kind. Moreover they contain unbroken shards. The mudstones are similar to the thin nongraded mudstone beds lower in the sequence, except the beds are much thicker. They probably represent long periods of quiet sedimentation.

The coarse-grained members of the Tangaratta Formation, the Garoo Conglomerate and the Gowrie Sandstone were deposited under different conditions of sedimentation. The Garoo Conglomerate is a greywacke with coarse conglomerate lenses, current bedding, angular mudstone chips and broken shallow water fossil remains. On the other hand, the Gowrie Sandstone is a fairly well sorted feldspathic arenite containing large scale current bedding foresets, and so represents a traction current deposit. The Garoo Conglomerate is the youngest coarse turbidite of the sequence in the Somerton–Attunga district.

The Tulcumba Sandstone: This unit has a basal orthoconglomerate overlain by a feldspathic and quartzo-feldspathic arenite which contains abundant calcite cement. Large scale current bedding foresets and ripple marks are the most common sedimentary structures in the sandstone, and hence the unit appears to be a traction current deposit. The appearance of abundant neritic fossils and the presence of a cross-bedded oolitic limestone within the formation, the Rangari Limestone (Voisey and Williams, in press), indicate a shallow water environment for the deposition of the Tulcumba Sandstone.

The Namoi Formation: In general the mudstones of this unit are massive, although some are laminated near its base. The sandstone lenses in the unit contain large scale current bed foresets and ripple marks and are well sorted. The absence of sedimentary structures in the mudstones suggests that they were deposited in a quiet environment as slowly settling muds. The arenites clearly are traction current deposits. The presence of abundant neritic fossils in the mudstones of the upper part of the formation indicates shallow water deposition. A local influx of coarse sediment has resulted in sandstone and conglomerate lenses which are present in the Namoi Formation, south of Somerton (see Fig. 2). Such local, coarse, round-stone conglomerates and arenites could have been deposited at the mouth of a river.

Thus, from the Baldwin Formation to the top of the Namoi Formation there is a transition from turbidites to traction current deposits. The Baldwin Formation is a sequence of turbidites in which coarse greywackes are abundant. The Mandowa Mudstone and the Tangaratta Formation contain much less frequent fine and coarse grained turbidites and more sediments reworked after deposition. The laminites I in these units were possibly presorted before being transported to their present position. Going up the sequence, muds deposited in a quiet, gradually shallowing environment become more and more abundant and turbidites give way to traction deposits. The Namoi Formation contains only muds and traction current deposits laid down in shallow water.

STRUCTURE.

The Somerton–Attunga district lies in the structural division called the "Western Belt of Folds and Thrusts" (Voisey, 1959). Structures defined by Voisey (1958), Chappell (1961) and Crook (1961) have been recognized and extended to this district. Folding of the sediments has been followed by the development of normal and transcurrent faults, low angle thrusts, and wrench faults. The structures are illustrated in the cross sections in Figure 3.

Folding: Folding commenced at or before the end of the deposition of the Baldwin sediments, which were eroded and overlain unconformably by the Keepit Conglomerate. The folding continued (or commenced again) before the deposition of the Tulcumba Sandstone, as indicated by the unconformity at the top of the Tangaratta Formation, and the final folding included the remaining sediments in the sequence. The folding was never intense and the regional axial trend of the major folds is north-north-west. Axial traces of gentle cross folds on the limbs of the major fold in the Baldwin Formation trend north eastwards, at about 80° to the major fold trend.

The Major Folds: The Goonoo Goonoo Anticline (Crook, 1961) is correlated with the Klori Anticline (Chappell, 1961), in the northern part of the district. The Marsden Park Syncline (Crook, 1961), the Appleby Syncline and the Mandowa Syncline (Chappell, 1961) lie along an axis of depression, east of the Goonoo Goonoo Anticline.

The northern continuation of this axis of depression is the Manilla Syncline (Voisey, 1958). Low amplitude north-north-west trending folds occur in the Tangaratta Formation north of Duri. The upper Tangaratta Formation and overlying sediments form the eastern limb of the Werrie Basin (Carey, 1937).

The Goonoo Goonoo Anticline is the major structural feature of the district and is flanked in most places by low hills of the Keepit Conglomerate. Cross-folded Baldwin sediments in the anticline may dip as much as 80°, but the Keepit Conglomerate and younger sediments do not dip more than 25° on the limbs of the anticline.

The Mandowa Syncline (Chappell, 1961) is a very gentle north-plunging structure that has been disrupted by the Baldwin Fault (Benson, 1917; Voisey, 1958) and the Appleby Fault. The Appleby Syncline, to the south of the Mandowa Syncline and on the same axis of depression, is an asymmetrical structure with dips of 55° on the eastern limb and 5° on the western limb. It is disrupted by the Appleby Fault and there is some complex small-scale folding near the south-east closure of the syncline, where the Appleby Fault bifurcates. Still further south along this axis of depression is the Marsden Park Syncline which is flanked by the gently dipping Keepit Conglomerate.

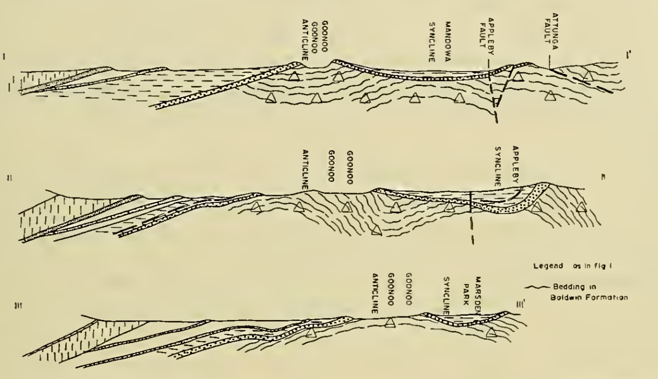

FIG 3 CROSS-SECTIONS TO ACCOMPANY THE GEOLOGICAL MAP OF THE SOMERTON - ATTUNGA DISTRICT

Figure 3.

To the west of the Goonoo Goonoo Anticline the Tangaratta Formation shows ill-defined low amplitude folds which do not appear in the overlying sediments. The upper part of the Tangaratta Formation and the overlying units dip at about 25° south-west and form the lower sediments of the eastern limb of the Werrie Basin (Carey, 1937).

The folds with axes trending north-east are subordinate to the regional north-west folds. The genetic relationships of the two axial trends have not been established, but the "cross folds" are most conspicuous in the Baldwin sediments. The younger rocks are not noticably "cross folded", but the common fold style developed in the sediments in this region is open non-cyclindroidal folding, i.e., domes and basins.

Faulting: Three types of faults occur in the district. These are, in order of formation, the Manilla Fault (Voisey, 1958), the Appleby Fault, the Attunga Fault (Chappell, 1961), the Baldwin Fault, and the Clay Gully Fault and similar minor wrench faults. The Appleby and Manilla Faults are normal faults with a strike component along the axial trend of the Appleby and Mandowa Synclines. The eastern blocks of sediment have moved up along the faults. These faults are offset by the Baldwin and the Attunga Faults which are low angle thrust planes on which the sediment has been thrust towards the west. The Baldwin Fault appears to die out on meeting the Attunga Fault. The Appleby Fault bifurcates near Appleby and has not been traced further south than the Clay Gully Fault. This fault, together with the minor wrench fault that offsets the Goonoo Goonoo Anticline north-west of Klori Trig. station, represents the last major fault movement in the district, and they are not affected by the other faults.

CONCLUSIONS.

1. Interpretation of the stratigraphy in the Somerton–Attunga district has been greatly influenced by the recognition of (*a*) Persistent marker beds in the sequence, of which the Tulcumba Sandstone and the Keepit Conglomerate are the most important because of their regional continuity; (*b*) The presence of two angular unconformities in the sequence; (*c*) The change in sedimentation, from turbidite deposition at the base to traction current deposition at the top of the sequence.

2. New light has been thrown on the tectonic history of the district by the recognition of the Bective and Onus Creek unconformities.

3. Carey (1937) and Voisey and Williams (in press) studied the western outcrops of this belt of sediments. Here, because the Tulcumba Sandstone unconformably overlies the Mandowa Mudstone (and the Tangaratta Formation is absent), they had no difficulty in establishing that the Tulcumba Sandstone was the lowest Carboniferous unit in the sequence and the top of the Mandowa Mudstone present here was the uppermost Devonian unit.

However, in the east, the junction between the Carboniferous rocks and the Devonian rocks is not so well defined. Here the Tangaratta Formation has been recognized as a unit which thickens towards the east, overlies the *Leptophloeum*-bearing Mandowa Mudstones and is unconformably overlain by the Tulcumba Sandstone. The unit itself contains marine shelly fossils and does not appear to contain *Leptophloeum australe* remains even though it has been mapped as a rock unit. The problem is then posed of where in this unit, in which the actual transition from turbidite to traction current deposit can be most closely pinpointed, does the Carboniferous-Devonian boundary occur? This problem can now only be solved by palaeontological investigations.

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